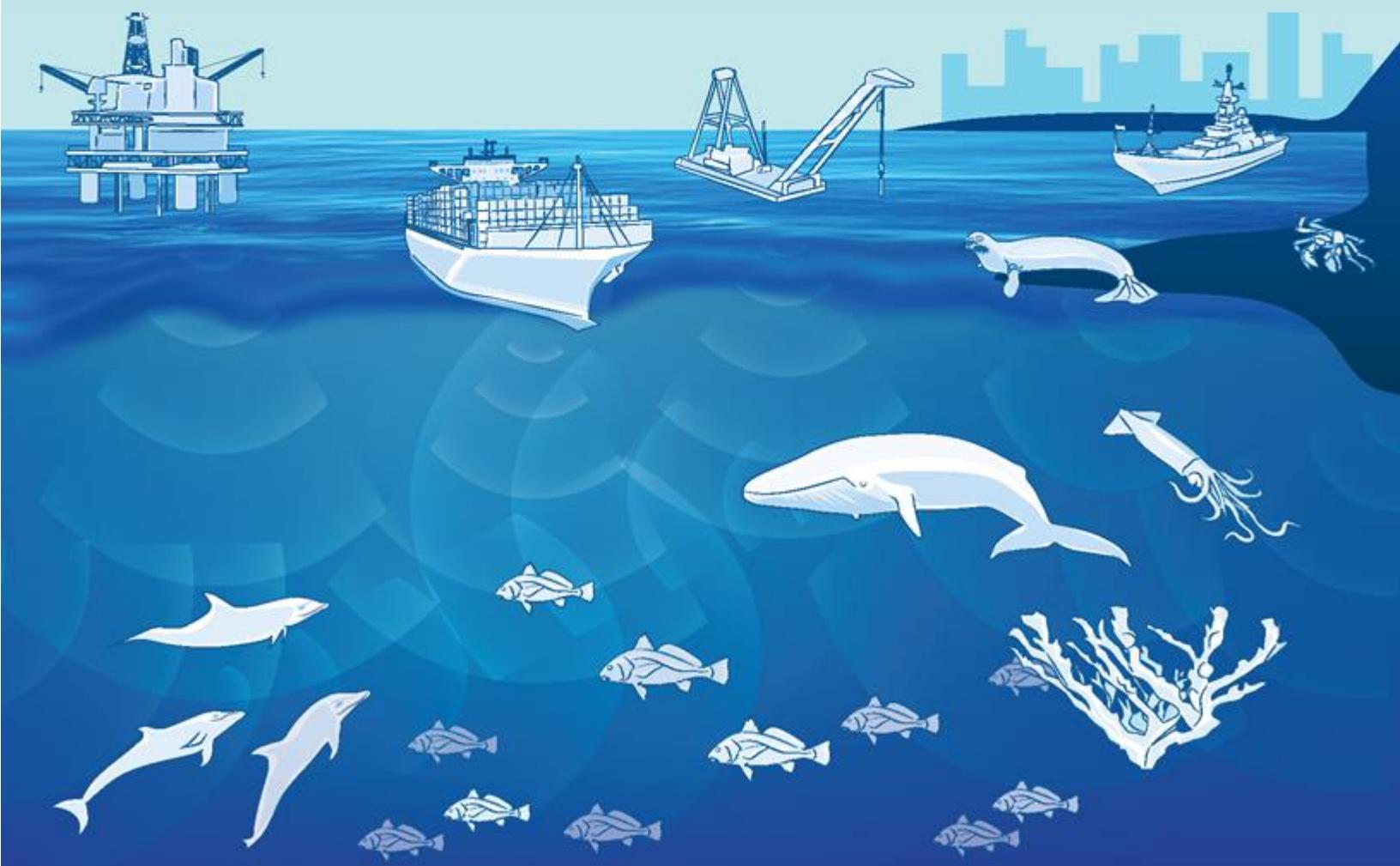


EXHIBIT 8



Ocean Noise Strategy Roadmap



Ocean Noise Strategy Roadmap

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Can You Hear Me Here? Managing Acoustic Habitat in U.S. Waters⁶

INTRODUCTION

The U.S. National Oceanic and Atmospheric Administration (NOAA) is a steward of the nation's oceans, with a variety of statutory mandates for conservation and management of coastal and marine ecosystems and resources of ecological, economic, and cultural significance. To this end, NOAA is charged with protecting the long-term health of a wide variety of aquatic animal populations and the habitats that support them, including whales, dolphins, sea turtles, fishes, and invertebrates. While these animals fill very different roles in marine ecosystems, many of them share a common and fundamental biological need: the ability to hear, produce, and respond to sound.

The purposeful use of sound for communication by marine mammals, many fish, and a few marine invertebrates is well documented (reviewed by Tyack & Clark 2000, Normandeau Associates 2012, Ladich 2015). For example, fin and blue whales produce low frequency calls that are thought to play roles in finding mates, sharing food resource information, and navigating at ocean basin scales (Payne & Webb 1971, Morano et al., 2012). In contrast, bottlenose dolphins use higher frequency signals to maintain social structure, identify individuals, and echolocate during foraging (Janik & Slater 1998). Some fish species are well known to produce loud low frequency choruses for communicating with conspecifics and attracting mates (Myrberg 1981). Cavitating bubbles produced by snapping shrimp emit sound upon their collapse that stun prey and provide a means for individuals to communicate with one another and defend territories (Versluis et al., 2000). In addition, there is evidence from both terrestrial and marine organisms illustrating the ecological importance of adventitious sounds: those gathered opportunistically from the surrounding habitat through eavesdropping rather than from a purposeful sender (Barber et al., 2010, Slabbekoorn et al., 2010, Radford et al., 2014).

Many animals hear and respond to frequencies outside of those they produce, underscoring the importance of eavesdropping on other species or of detecting meaningful sounds made by the physical environment. Aquatic examples are wide ranging, including baleen whales responding to sounds within frequencies used by killer whales (e.g., Goldbogen et al., 2013), herring detecting sounds used by echolocating whales, fish and crab larvae using reef sounds dominated by snapping shrimp as directional cues, sharks approaching the sounds made by struggling prey and surface-feeding fish responding to sounds of prey falling into the water (reviewed by Slabbekoorn et al., 2010, p. 183). Barber et al. (2010) summarize a pattern that appears broadly consistent for both terrestrial and marine realms: *"It is clear that the acoustical environment is not a collection of private conversations between signaler and receiver but an interconnected landscape of information networks"*. As defined for humans by the International Standards Organization (2014), soundscapes are a "perceptual construct" inclusive of all the sounds *perceived* by people in a place. Wildlife ecologists, however, more typically characterize soundscapes as all the sounds *present* in a particular location and time (Pijanowski et al., 2011). The complex and dynamic assemblages of natural sounds that contribute to soundscapes are inherent aspects of discrete marine habitats inhabited by individual species and ecological communities (Figure 2-1). Thus, as experienced by the animals inhabiting it, a soundscape may also be referred to as "acoustic habitat" (Clark et al., 2009, Moore et al., 2012a, Merchant et al., 2015).

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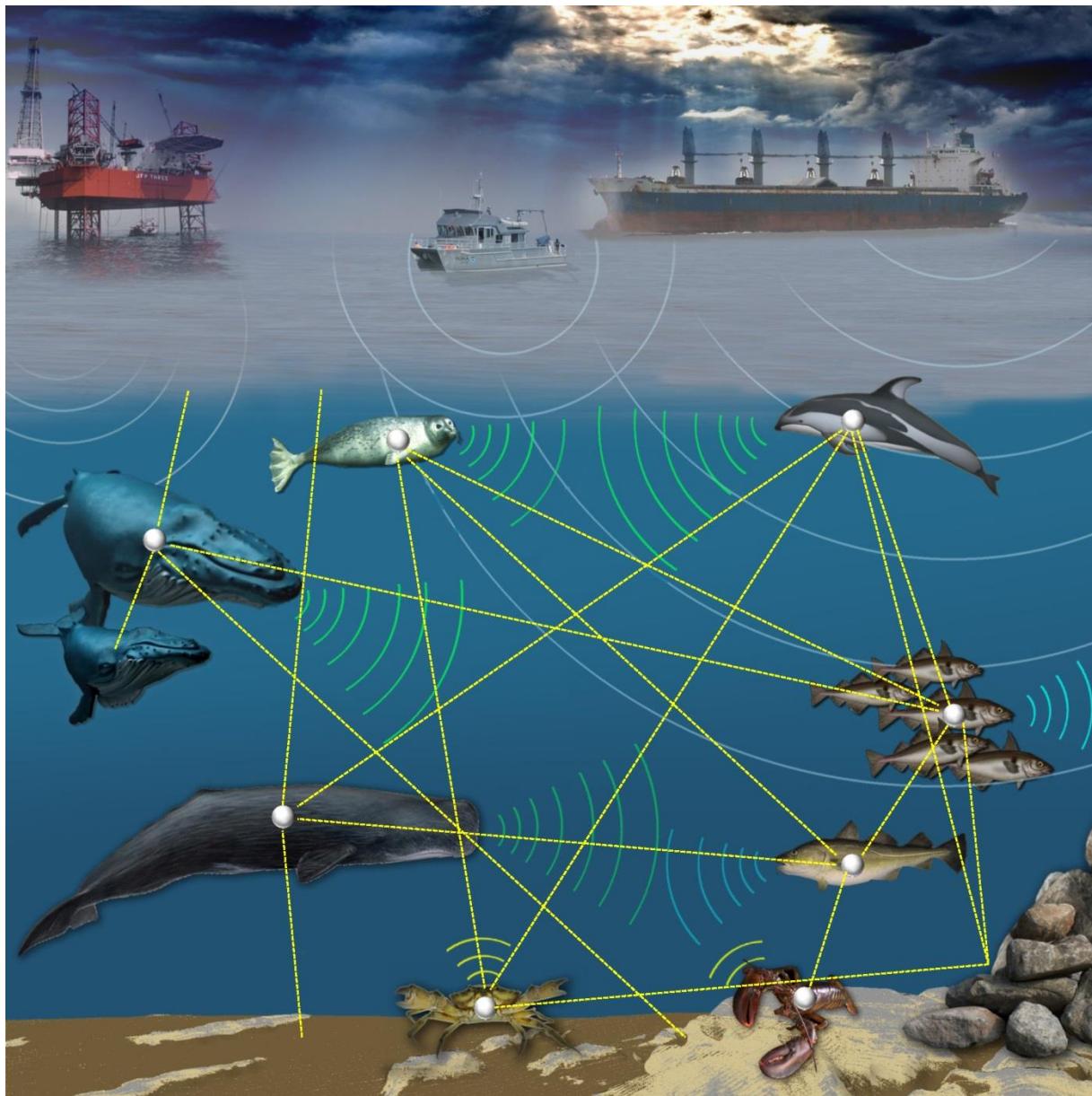


Figure 2-1. Potential acoustically mediated information pathways (yellow dotted lines) in a marine community, including, but not limited to, purposeful communication between individuals, use of echolocation over distances (large and small), eavesdropping on sounds made by other animals, detection of human activities, and identification of seafloor characteristics, all supporting biologically important behaviors such as settlement, recruitment, feeding, migration, and reproduction. White circles and blue, green and yellow semicircles generically represent information-gathering opportunities and sound production, respectively.

Acoustic habitats identified today are often significantly modified by noise produced by human activities, and thus efforts must be made to characterize both their natural and altered conditions. Such activities, and the resulting noise levels that they produce, are increasing throughout coastal and ocean waters in both time and distribution. There are few aquatic areas where anthropogenic noise is absent. Changes in noise conditions over time are predicted to vary considerably among ocean and coastal areas. In some

heavily used areas, several-fold increases in the contribution of human noise to acoustic habitats have been measured over just a few decades (Andrews et al., 2002, McDonald et al., 2006). While some marine animals are capable of adjusting communication signals in the presence of noise (e.g., Holt et al., 2009, Parks et al., 2010), it is unknown whether these changes can transfer between generations or whether they result in long-term fitness consequences (see Francis and Barber, 2013 for discussion of evolutionary traps and maladaptive consequences of signal modification in the presence of noise). As reviewed by Erbe et al. (2016), animals have evolved some mechanisms to improve their ability to perceive signals of biological importance in the presence of some noise. However, relative to the life spans of marine organisms, noise levels in many coastal and offshore areas have seen significant growth over just a handful (e.g., some fish, turtles and marine mammals) to tens (e.g., some fish and invertebrates) of generations. Given this rapid increase, the potential for evolved mechanisms to ameliorate loss of acoustic information in many contemporary noise environments is likely to be limited. Additionally, Barber et al. (2010) remind us that while evolutionary adaptation to reduce masking of communication signals can act on both conspecific senders and receivers, mechanisms to improve perception of a wide variety of incidental sounds relative to a wide variety of noise types must be far less singularly focused (resulting in less selective pressure) and are limited to the listeners.

NOAA recognizes the need to develop an approach to underwater noise management that considers not only its effects on individual animals, but also the importance of natural sounds in the places where those animals live. As the world's coasts and oceans become busier and noisier, NOAA will be challenged to craft and implement new management approaches that balance the competing needs of coastal and ocean resource users and natural acoustic habitats. In this paper, we describe key elements of an agency-wide strategy to more comprehensively manage noise impacts to acoustic habitats, including implications for the science needed to assess habitat status and noise influences. We then examine NOAA's management tools and consider their application to acoustic habitat protection goals, highlighting activities that are underway or could be undertaken to achieve these goals.

BROADENING NOAA'S NOISE MANAGEMENT APPROACH

Describing Acoustic Habitats

The place where an animal lives is called its “habitat” and is described by its physical and biological attributes, including its acoustic conditions. Under strict habitat definitions, acoustic habitat is an attribute of the area surrounding individual animals; however, the concept is commonly expanded to refer to habitat as the place where multiple species occur together under similar environmental conditions. A habitat can therefore be distinguished from surrounding habitats on the basis of both its species composition and its physical environmental characteristics (e.g., type of seabed, tidal currents, salinity). An acoustic habitat can similarly be attributed to an assemblage of species that are known to collectively experience and often contribute to a natural soundscape that is distinguishable from surrounding soundscapes. Soundscape measurements can be associated with aquatic habitats that have been classified using more traditional data types (e.g., McWilliams & Hawkins 2013, Lillis et al., 2014). Such measurements can illustrate variance in space, time, and frequency content, depending on what species are present at the time of measurement. For example, natural acoustic habitats within tropical reef areas may be heavily dominated by the popping of snapping shrimp and will therefore differ dramatically from those within temperate boulder fields inhabited by the grunting and thrumming of fish such as cusk, sculpin and cod (e.g., Rountree et al., 2006, Staaterman et al., 2013). Acoustic habitats may vary seasonally in association with the presence of animals that produce sounds, whether they are feeding, reproducing, or simply migrating through the area (e.g., Moore et al., 2012b, Parks et al., 2014). Environmental sources of sound can also show strong temporal trends, such as louder, stormier winter